

## PATENT SPECIFICATION

DRAWINGS ATTACHED



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## COMPLETE SPECIFICATION

## Improvements in and relating to the Mixing of Materials

We, VOMETEC N.V., a limited company organised under the laws of the Netherlands, of Voorthuizen (de Ruyterlaan 2), the Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 This invention relates to a method of mixing solid materials, such as granular solids, either alone or with other solid materials, or with fluids, and also relates to an apparatus for carrying out said method.

15 It is known to put granular solids which are to be mixed into a container and thereafter subject them to an air current, which is introduced into the container at the bottom thereof and forms a column of air through the solids, the velocity of the air current being greatest at its nucleus (i.e. along the axis of the air current) and least in the region of the periphery of the current.

20 This procedure causes the solids to move laterally inwards towards the nucleus of the air current which conveys the solid upwards towards the top of the container. At the upper end of the column, the solids entrained in the conveying air current are carried clear of the bulk of the solids and spill over radially into an annulus which forms a column of descending solids in the region of the walls of the container.

35 However, it is often desired to mix solid components which differ widely in their weight and, in such cases, difficulty arises since, if the velocity of the nucleus of the air current i.e. the conveying air current, is held low enough so as not to cause the lighter components to be carried clear of the bulk of the materials and, possibly to the top of the container to which they may stick, then the heavier components will not be moved by the periphery of the air

current. Alternatively, if the velocity of the air current is adjusted so as to enable the heavier components to be moved satisfactorily, then the lighter components will be carried clear of the bulk of the material in the container and, as mentioned above, they may stick to the top of the container. In either case the efficiency of the mixing is poor.

50 According to one aspect of the invention, there is provided a method of mixing solid materials, such as granular solids, either alone or with other solid materials or fluids, which method comprises placing one or more solid materials to be mixed in a mixing container having an expansion chamber communicating with the top thereof, and subjecting the materials to one or more gas streams which are introduced into the container through a bottom portion thereof, whereby the materials form a dense-phase gas fluidised bed in which one or more conveying gas currents are produced, the velocity of each of said conveying gas currents whilst in the mixing container being greater than the minimum velocity required to convey the heaviest material clear of said dense-phase gas fluidised bed and the velocity of each of said conveying gas currents when in the expansion chamber being caused by the expansion chamber rapidly to decrease to below the velocity required to maintain the movement of the lightest material in an upward direction, whereby the solid materials within said expansion chamber are caused to return to the mixing container.

55 If it is desired to mix, in the mixing container a solid material with a liquid, the fluid may be introduced into the container by entraining the liquid into said gas stream.

60 In one embodiment of the invention, the materials are formed into the dense-phase fluidized bed by introducing a fluidizing gas current into the mixing container through a porous plate, which forms the

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bottom of the container. The conveying gas currents are introduced into the mixing container by way of inlet means provided in said porous plate.

5 Advantageously, the velocity of the conveying gas currents introduced into the container through the inlet means arranged in the porous plate, is adjusted to exceed, or at least to be equal to, the minimum conveying velocity of the heaviest component of the mixture of materials when said mixture passes the boundary plane between the mixing container and the expansion chamber arranged on top of said container.

10 According to another aspect of the invention there is provided an apparatus for mixing solid materials, such as granular solids, either alone or with other solid materials or fluids, which apparatus comprises a mixing container having a porous bottom through which a fluidizing gas current can be introduced into said mixing container, one or more inlet means in said porous bottom through which means a conveying gas current can be introduced into said container, the top of the mixing container communicating with an expansion chamber wherein the velocity of the conveying gas current can be reduced rapidly so as to cause any material entrained in said conveying gas current to return to the container.

15 In order to accurately control the velocity of the fluidizing gas, the container may be formed with a chamber at the bottom thereof, the upper wall of the chamber being formed by the porous bottom of the container. The fluidizing gas may be introduced into the chamber by means of a conduit and the velocity adjusted as desired by known control methods.

20 Preferably, the apparatus is arranged with the walls of the expansion chamber, which communicates with the top of the mixing container, diverging from the boundary plane between said chamber and container to form a substantially conically-shaped chamber. The height of said expansion chamber is arranged so that it causes the velocity of the gas current entering therein and carrying the mixture of materials to be mixed to be reduced very quickly to a value lying below that required to maintain the movement of the slightest component present in said mixture of materials in an upward direction. As a result of expansion the materials which are carried into the expansion chamber, return along the walls of said expansion chamber into the mixing container.

25 When the conveying gas current is introduced into the mixing container by more than one inlet means, then the inlet means are advantageously distributed in a suitable pattern over the porous bottom of the mixing container.

If, for example, the bottom of the container is shaped in the form of a frustum of a cone, the lowest part thereof forming an outlet for emptying the container, then the several gas inlet means are arranged in a configuration about this outlet.

30 In order to introduce a fluid e.g. a liquid, into the mixing container one or more of the gas inlet means are provided with a centri type portion, preferably arranged at the end of the inlet means, said portion co-operating with one or more supply tubes for feeding the fluid into the container.

35 It will be appreciated that the mixture of materials deposited in the container are forced by means of the gas stream entering into the container through its porous bottom, into a state in which they form a so-called "dense-phase" gas fluidized bed, whilst the conveying gas entering into said container by means of the gas inlet means will produce at one or more points of said dense-phase fluidized bed, channels containing conically diverging, vigorous and upwardly directed gas streams. The gas streams carry part of the materials upwards into the expansion vessel from which they return into the mixing vessel. As a result of the vigorous gas streams, the materials in the container will be drawn out of the dense-phase fluidized bed into the streams, which carry said materials upwards into the expansion chamber where they spill out radially and return to the fluidized bed. Moreover, when a liquid or the like is introduced into the container by passage through a gas inlet means, then as a result of the very high velocity of the gas stream on entry into the container, said liquid will be distributed throughout the conically diverging gas stream within the container in a very finely divided state thus ensuring an intimate mixing of this finely distributed liquid with the other materials.

40 For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:—

45 Figure 1 is a diagrammatic longitudinal cross-section of a mixing apparatus;

50 Figure 2 is a cross-section of an inlet means whereby a liquid can be introduced into the apparatus;

55 Figure 3 is a plan view of the mixing apparatus shown in Figure 4; and

60 Figure 4 is a cross-section taken along the line IV—IV of Figure 3.

Referring first to Figure 1 of the accompanying drawings, a mixing container which is of a cylindrical shape, is provided at the bottom thereof with a chamber 5 which is separated from the container 1 by a porous plate 3. A first conduit 4 leads into chamber 5 and provides means whereby

a gas A at a known adjustable pressure can be introduced into said chamber whence it can enter container 1 by passing through the porous plate 3. An inlet means 6 passes through the non-porous wall 2 of chamber 5 and, by means of aperture 7 in plate 3, leads into the bottom centre of the mixing container 1. A second conduit 9 is connected to inlet means 6 thereby enabling a gas B to be supplied to the container 1.

The dimensions of the conduits 4 and 8, the inlet means 6, the aperture 7 and the chamber 5 determine the pressures at which the gases A and B are supplied to the apparatus. The gas A, i.e. the gas entering container 1 through the porous plate 3, has a considerably lower exhaust velocity than the gas B, which enters container 1 through the aperture 7.

The velocities of gases A and B on entering the mixing container are such that the velocity of gas A, i.e. the gas fluidizing the contents of the mixing container 1, does not reach a value high enough to remove the solid materials completely whereas that of the conveying gas B entering through the aperture 7 exceeds the conveying velocity of the heaviest component of the mixture of materials.

As a result, the materials to be mixed are carried continuously upwards by gas B in a vigorous diverging conically shaped air stream till they arrive at the top of said mixing container 1, the suction produced thereby within the mixing container forcing the materials out of the fluidized bed, as formed by gas A, into the circular movement produced by said vigorous air stream. The small arrows C depicted in the mixing container illustrate in a general sense the movement of the materials. At the end of the upward movement the materials travel in the direction of the arrows D into an expansion vessel 9 which is arranged on top of the mixing container 1. In this expansion vessel 9, the velocity of the gas in the conical diverging air stream decreases rapidly and falls to below that required to maintain the movement of the lightest component of the materials to be mixed in an upward direction, consequently said materials will spill over and disperse into a more or less outwardly bent path returning along the walls of the expansion vessel 9 into the container 1 (as depicted by the arrows E). This procedure is continuous. In some cases it is possible that very light particles of the materials move upwardly into the region of the top of the apparatus (see the arrows F) although this is, of course, avoided as much as possible. However, in this connection material catchers 11 are provided in the uppermost part 10 of the device. The very fine particles are caught

in these catchers in the manner indicated by the arrows G. It will be appreciated that normally one or more closable inlets (not shown) to deposit the materials into the apparatus are provided.

When applying the method of the invention, the mixing container 1 is normally only partly filled up so that initially the materials to be mixed reach up to the level 12. The materials fall back from the expansion vessel 9 according to the arrows E, and pass through the uppermost originally unfilled, part of the mixing container 1 and re-mix with the materials present in the dense-phase fluidized bed. When the mixing process is finished, the resulting product is removed from the container 1 by various means known to the art.

Figure 1 also indicates diagrammatically a method of feeding a liquid H into the mixing container 1 by way of a tube 13, said liquid forming one of the components to be mixed. By providing the tube 13 with a venturi type delivery means, preferably at a point near to the end of said tube 13 in the inlet means 6 the conveying gas streaming at a high velocity through the inlet means 6 automatically sucks liquid from out the tube 13, thereby distributing said liquid very finely in the gas stream which enters at a high exhaust velocity into the mixing container 1. This furthers to a considerable extent the intimate mixing of the liquid H with the other materials to be mixed therewith.

A particular embodiment of such a venturi-type delivery means is shown diagrammatically in Figure 2. In this case the inlet means 6 is itself formed with a venturi type part 14 having inlet apertures 16 arranged in the narrowest part 15. Further the part 14 is surrounded by a liquid container 17 which is sealed to the wall of the tube 6. A conduit 18 has one end leading into said liquid container 17 and the other end placed in a liquid 19 contained in tank 20. The gas stream as represented by B sucks the liquid 19 into the liquid container 17 according to the arrows K thereby filling up this container completely. The liquid 19 will enter into the inlet means 6 through the inlet apertures 16. Immediately beyond the part 14 there is effected the beginning of a conical spread of the gas stream in which the liquid is very finely distributed (as shown by the arrows L).

The apparatus is not limited to having only one inlet means 6 wherein the conveying gas B is introduced into the mixing container 1 through aperture 7. On the contrary, it is possible to have in one mixture container more than one gas inlet means; consequently more vigorous upwardly directed gas streams are produced

at several points in the mixing container. Figures 3 and 4 show four apertures 21 of gas inlet means 22 arranged in a mixing container 23. This mixing container 23 has a tapered bottom end portion 24 with a flat bottom wall 25. The gas tubes 22 are positioned about the centre of the flat bottom wall 25 so as to leave the same perfectly free. This central portion can be opened and closed again by a shut off 26 with a pull rod 27 as shown diagrammatically in Figure 4. The mixing vessel 23 is provided in this embodiment with two porous plates 28 and 29 extending in a direction parallel to the wall of the tapered bottom end portion 24, whereby the fluidizing gas can enter the container 23. The product obtained after use of the apparatus can be easily discharged from the mixing vessel by pulling downwards the shut off 26.

#### WHAT WE CLAIM IS:—

1. A method of mixing solid materials, such as granular solids, either alone or with other solid materials or fluids, which method comprises placing one or more solid materials which are to be mixed together or with a fluid, in a mixing container having an expansion chamber communicating with the top thereof, and subjecting the materials to one or more gas streams which are introduced into the container through a bottom portion thereof, whereby the materials form a dense-phase gas fluidized bed in which one or more conveying gas currents are produced, the velocity of each of said conveying gas currents whilst in the mixing container being greater than the minimum velocity required to convey the heaviest material clear of said dense-phase gas fluidized bed and the velocity of each of said conveying gas currents when in the expansion chamber being caused by the expansion chamber rapidly to decrease to below the velocity required to maintain the movement of the lightest material in an upward direction, whereby the solid materials within said expansion chamber are caused to return to the mixing container.

2. A method according to Claim 1, wherein the bottom of the container is a porous plate and the dense-phase gas fluidized bed is formed by introducing a fluidizing gas current into the mixing container through the porous plate, the conveying gas current being formed in the fluidized bed by one or more additional currents introduced into the container through inlet means provided in the porous plate.

3. A method according to Claim 1 or 2, wherein the velocity of the nucleus of each of the conveying gas currents is adjusted so that the velocity of the conveying gas current remains greater or at least

equal to the minimum conveying velocity of the heaviest component of the mixture of materials when said mixture passes the boundary plane between the mixing container and the expansion chamber arranged on top of said mixing container.

4. A method according to Claim 1, 2 or 3, wherein a liquid is supplied to one or more of the conveying gas currents, said liquid forming one of the materials to be mixed.

5. A method of mixing materials, substantially as described with reference to the accompanying drawings.

6. An apparatus for mixing solid materials, such as granular solids either alone or with other solid materials or fluids, which apparatus comprises a mixing container having a porous bottom through which a fluidizing gas current can be introduced into said mixing container, one or more inlet means in said porous bottom through which means a conveying gas current can be introduced into said container, the top of the mixing container communicating with an expansion chamber.

7. An apparatus according to Claim 6, wherein the bottom of the mixing container is provided with a chamber, the upper wall of said chamber being formed by the porous bottom of the mixing container, fluidizing gas being introduced into the chamber through a conduit attached thereto.

8. An apparatus according to Claim 6 or 7, wherein the walls of the expansion chamber on top of the mixing container diverge from the boundary plane between said mixing container and expansion chamber, the shape and height of said expansion chamber being arranged so that when the apparatus is in use the velocity of a gas current entering into said expansion chamber and carrying a mixture of materials from a dense-phase gas fluidized bed formed in said mixing container is reduced rapidly to a value lying below that required to maintain the movement of the lightest component in said mixture of materials in an upward direction, whereby the materials are caused to return along the walls of said expansion chamber into the mixing container.

9. An apparatus according to Claim 6, 7 or 8 wherein more than one conveying gas inlet means is provided in the bottom of the container.

10. An apparatus according to Claim 6, 7, 8 or 9, wherein the lower portion of the mixing container is conically shaped the lowest part thereof forming an outlet for emptying the mixing container, the conveying gas inlet means being arranged in a configuration about said outlet.

11. An apparatus according to any one of Claims 6 to 10, wherein one or more of the conveying gas inlet means are provided

with a venturi type portion arranged at the end of the inlet adjacent the mixing container, said portion co-operating with one or more supply conduits for feeding a  
5 liquid into the mixing container.

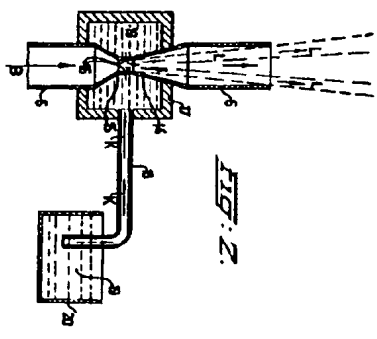
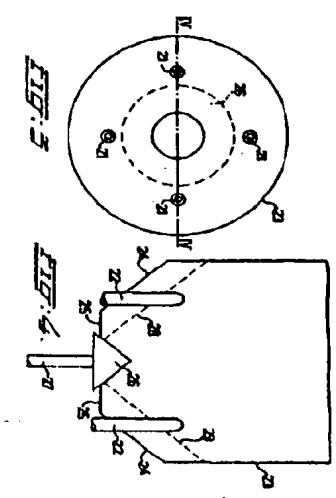
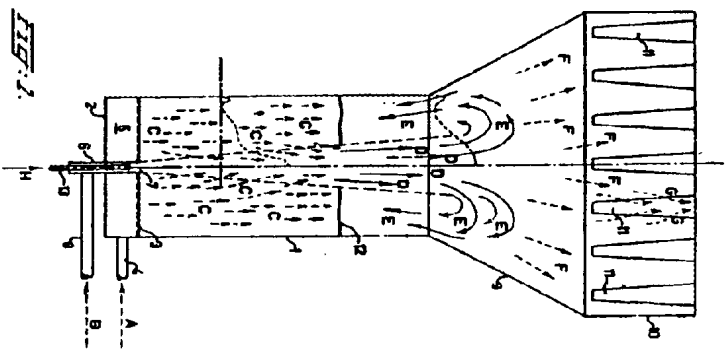
12. An apparatus for mixing materials, substantially as described with reference to,

and as shown in, the accompanying drawings.

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